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The Influences of Integrating Information Technology into Discussion-based Concept Cartoons on 5th Graders' Mathematics Learning

Tzu-Hua HUANG*

Department of Education
University of Taipei

Tzu-Ying LI

Ta-Pu Elementary School, New Taipei City

This study established a cartoon-based mathematics concept learning system. It examined the effect of three different teaching modules, discussion-based concept cartoons (n = 29), teacher-oriented concept cartoons (n = 26), and worksheet teaching (n = 23), on the mathematics achievement of fifth graders in Taiwan. Two groups of students used computers to learn mathematics with concept cartoons, and the other one used a worksheet. It was found that the group using discussion-based concept cartoons performed significantly better than the other two groups, and students taught with discussion-based concept cartoons with computers achieved better performance than those taught with the conventional method.

Keywords: concept cartoon; discussion-based learning; mathematics achievement; computer-assisted instruction

* Corresponding author: Tzu-Hua HUANG (anteater1029@mail2000.com.tw)

Introduction

Elementary school mathematics teachers in Taiwan have given lectures and used conventional teaching materials, and students have learned independently in class without any interaction. This made conventional classes tedious, which was difficult for students to remain focused (C. S. J. Huang, Su, Yang, & Liou, 2017). When students had lower learning intentions, it was difficult for them to understand and memorize mathematics concepts (Cankoy & Tut, 2002; Pilli & Aksu, 2013). Compared with conventional teaching methods, discussion-based teaching could broaden students' way of thinking and let students participate in learning. Discussion-based learning emphasizes interactions between teachers and students, as well as among students. The exchange of ideas and opinions makes the ideas and concepts clearer and enables students to form different opinions. Hence, classroom discussions have become an essential part of modern mathematics education (Chen & Liu, 2002).

The humorous faces in cartoons are extremely appealing to students, which have increased the confidence in using cartoons as teaching materials. The selection of suitable cartoons or comics for teaching and learning helped students' mental development and critical thinking (Şengül & Dereli, 2010). Dabell (2008) argued that concept cartoons, which were a type of visual argument designed in a cartoon style, with mathematics-related dialogue from different perspectives presented in dialogue boxes could be used as a medium to guide further conversation and discussion among learners and to encourage learners to view problems from different angles. Demirci and Özyürek (2017) also stated that concept cartoons were a useful tool for students' cognitive development, helped to develop students' advanced critical thinking abilities, and made students reflect on their thoughts or feelings, creating an active environment for discussion in class. Besides, the use of computers had much more flexibility, allowing for more cooperative learning. Hence, the current study of this research was to develop a discussion-based concept cartoon system that helped learners to reconstruct mathematics knowledge by discussing while watching the concept cartoons.

Literature Review

Concept Cartoon

Whether at the individual or national level, mathematics ability was considered a key component for personal and economic development, and mathematics-related skills were also becoming more critical (Lipnevich, MacCann, Krumm, Burrus, & Roberts, 2011). In conventional teaching, students gained mathematics knowledge through the teacher directly teaching formulas and often focused only on rules and problem-solving techniques. This caused students to lose interest and no longer find mathematics fun (Chen & Liu, 2002).

Constructivism is a late learning theory whose central premise is exploring alternative structures and related misconceptions of learners in the learning process. The constructivist’s claim regarding the learner’s knowledge construction process is that knowledge is derived from the interaction between the learner’s own prior knowledge and the learning context (Guo, 1988; Matthews, 1994; Yager, 1991).

Cartoons and comics are attracting more considerable attention in the education community, and some teachers have started to view cartoons and comics as potential teaching tools, applying them during their teaching to increase students’ interest in subjects (Cleaver, 2008). Kusumaningrum, Ashadi, and Indriyanti (2018) argued that concept cartoons were practical tools to detect students’ misconceptions on a science topic. In the past two decades, the discussion of children’s scientific concepts has been based on the knowledge theory and learning theory of constructivism, which has gradually become the most considerable influence in science and mathematics education. Concept changing has almost become synonymous with scientific learning (Mortimer, 1995). Demirci and Özyürek (2017) found that the text and pictures in concept cartoons attracted students’ attention and increased their learning motivation and attitudes. This indicated that concept cartoons were a useful tool for students’ cognitive development, helped to develop students’ advanced critical thinking abilities, and made students reflect on their thoughts or feelings, creating an active environment for discussion in class.

Each concept cartoon is a simple independent picture that shows a situation well known to pupils from school or everyday reality, and a group of several children discussing the case through a bubble-dialog (Samková, 2018; Simon, Johnson, Cavell, & Parsons, 2012). The alternate conceptions posed within thought bubbles in concept cartoons could reduce chidren’s anxiety when discussing their thoughts, promoting argumentation and dialogic talk (Alexander & Wolfe, 2008; Kinchin, 2004; Sexton, Gervasoni, & Brandenburg, 2009), and establishing a conversation to produce reasoning surrounding scientific concepts (Woolman, 2019). Şengül (2011) stated that concept cartoons could influence students’ self-efficacy in learning mathematics because many students preferred concept cartoons, and concept cartoons could effectively improve the interest and effectiveness of learning mathematics. Şengül and Dereli (2013) argued that the use of cartoon teaching not only increased the attention of students but also allowed them to have a pleasant learning experience in an interactive learning environment.

Discussion-based Learning

Interaction among learners was crucial to the process of knowledge construction (H. J. So, Tan, & Tay, 2012; W. M. W. So & Ching, 2011). Bahar and Tongaç (2009) claimed that active knowledge builders were those who interacted with their environment, instructor, and peers (Liu, Cheng, & Lin, 2013). In recent years, teacher-student interaction has been emphasized, supporting the assertion that the discussion method could help teachers achieve adaptive instruction (Yang, 1999). Discussion methods could have beneficial effects related to peer interactions as long as students were appropriately supported by guiding questions from their teacher (Erickson & Herbst, 2018; Ge & Land, 2003).

Compared with conventional teaching methods, discussion-based teaching could broaden students' way of thinking and let students participate in learning instead of passively listening to lectures. Discussion groups, which provided students with the opportunity to interact and discuss the material in small breakout groups (as opposed to the class as a whole), were one such collaborative learning technique that instructors could implement in the classroom (Walker et al., 2018). As students socially interacted through an in-class discussion along with argument-based inquiry, their claims and evidence as forms of knowledge could be socially communicated, negotiated, critiqued, validated, and reconstructed (Choi & Hand, 2020). In the discussion and sharing process of students, the teacher could understand students' comprehension of the contents and their way of thinking and discovered students' misconceptions in the learning process (Jang, 1997).

O'Connor (2001) conducted a case study of 3 days of whole-class discussion in a fifth-grade mathematics classroom and found that discussions afforded opportunities for types of mathematical thinking, including the development and testing of hypotheses that were not seen in the typical mathematics classroom. A conceptual discussion between students was an effective means of reducing misconceptions and found to be significantly effective in improving students' achievement (Eryilmaz, 2002).

Computer-assisted Learning

There has been more considerable research on the influence of computer-assisted environments on mathematics instruction (Gunbas, 2015; Harskamp & Suhre, 2006; K. H. Huang & Ke, 2009; Li & Ma, 2010; Schoppek & Tulis, 2010). There was empirical evidence that computer-assisted learning environments played a role in students' learning enhancement and motivation (Lopez-Morteo & López, 2007). For example, Panaoura (2012) investigated the improvement of students' mathematical performance with a mathematical model via a computerized approach, and showed that students bolstered their problem-solving abilities. Tablet computers were the main learning aids, and the students discussed and interacted with each other by using these tablet computers. Owing to the use of tablet computers, there was much more flexibility, allowing for more cooperative learning. The touchscreen of a tablet enabled children with limited excellent motor skills to operate the device with their fingers, eliminating the more complex hand-eye coordination required to use a keyboard and mouse (Cooper, 2005). Moreover, tablets were lightweight and mobile, permitting children to play with them indoors and outdoors (Neumann & Neumann, 2014). Therefore, using a tablet could be considered as one of the best methods for teaching and students' learning.

According to past studies, concept cartoons were rarely used in mathematics, and most that has been used were teacher-oriented concept cartoons. There were no studies on the use of concept cartoons in teaching with the discussion-based method. A discussion-based concept cartoon system was established to ascertain the effect of different modules (teacher-oriented concept cartoon teaching, discussion-based concept cartoon teaching, and worksheet teaching) on students' learning achievement. This study combined concept cartoons and discussion-based learning into a learning system for students to discuss mathematics concepts, making students the protagonist in a teaching scenario where they might be able to learn mathematics effectively.

Methodology

Research Subjects

The research subjects were 78 fifth graders, whose mean age was 11, of an elementary school in Banqiao District, New Taipei City. The school emphasized a student-centered teaching method and promoted mobile learning. Every student was able to use mobile devices as a learning tool comfortably. Hence, this study took the school's students as research subjects. They were divided into three groups: the discussion-based concept cartoon group (n = 29), the teacher-oriented concept cartoon group (n = 26), and the worksheet group (*n* = 23). Subjects were randomly assigned into these three groups, and the groups were in a different class. Each group experienced a different teaching module. The subjects were anonymous and represented by code numbers.

Research Design

The research structure was divided into three parts: independent variable, control variable, and dependent variable. The independent variable of this study was the discussion-based concept cartoon group, the teacher-oriented concept cartoon group, and the worksheet group. The discussion-based concept cartoon group was provided with a review of mathematics concepts after teaching. Students of this group were divided into groups to discuss mathematics concepts, and then the teacher allowed students to select the idea they believed to be correct. The teacher-oriented concept cartoon group was provided with a review of mathematics concepts after teaching. Students of this group relied on the teacher to offer different concepts, and then the teacher allowed students to select the concept they believed to be correct. The worksheet group was provided with a review of mathematics concepts after teaching and required the teacher to offer worksheets to review concepts. Three methods of teaching were held in different classrooms and at different times. The research variables were shown in Table 1.

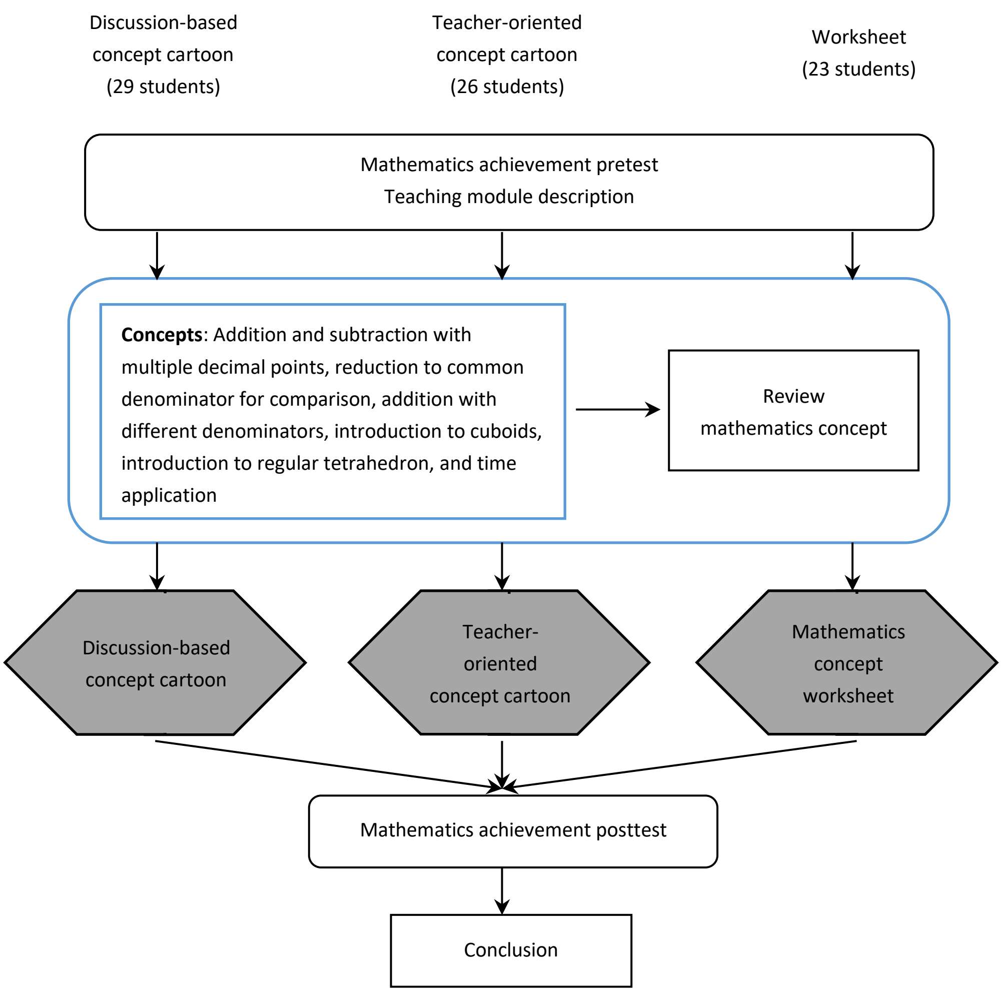
Table 1: Research Variables

Independent variable	1. The discussion-based concept cartoon group 2. The teacher-oriented concept cartoon group 3. The worksheet group
Dependent variable	Mathematics achievement
Control variable	1. The research subjects were all fifth graders with no significant differences in their mathematics achievement pretest scores. 2. The teaching contents include four lessons and six concepts. The four lessons were decimals, fractions, cuboids and regular tetrahedron, and time calculation. The six concepts were addition and subtraction with multiple decimal points, reduction to a common denominator for comparison, addition with different denominators, introduction to cuboids, introduction to regular tetrahedron, and time application. 3. Each class was 40 minutes long, and a total of 6 classes were taught. 4. Students were all taught by the same teacher. 5. The classes were all taught in a regular classroom. 6. The test items were the same for all three groups. 7. The students used different learning methods during the teacher's teaching in each class.

Research Process

The research subjects took a mathematics achievement pretest and were introduced to either one teaching module one week before the teaching experiment. The purpose of the pretest was to understand the initial mathematics achievement of the subjects so that it could be compared with their mathematics achievement after being taught with the different teaching modules. The subjects began taking classes with the various modules after completing the pretest. The discussion-based concept cartoon group and the teacher-oriented concept cartoon group used desktop computers to operate the concept cartoon system, and the worksheet group used a worksheet. After the six concepts were taught, a mathematics achievement posttest was administered. The research structure was shown in Figure 1.

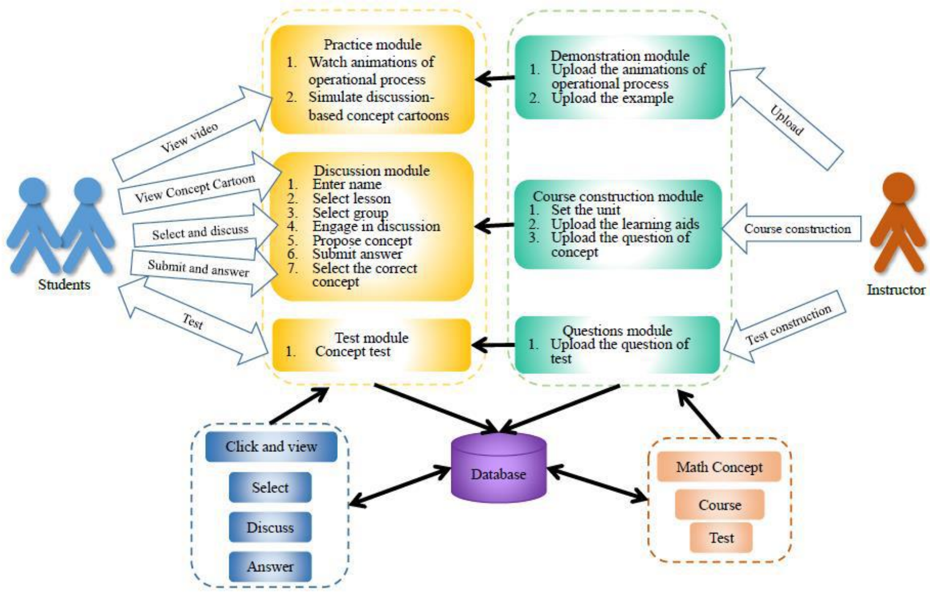
Figure 1: Research Structure



Concept Cartoon System

The concept cartoon system developed for this study was divided into discussion-based and teacher-oriented. The discussion-based concept cartoon system included a practice module, a discussion module, and a test module. The teacher-oriented concept cartoon system consisted of a demonstration module, a course construction module, and a questions module. The system was operated using a desktop computer with the parts "Practice module," "Discussion module," and "Teacher demonstration module." The "Test module" was operated using a tablet computer. The system structure of discussion-based concept cartoon was shown in Figure 2.

Figure 2: The System Structure of Discussion-based Concept Cartoon



Discussion-based concept cartoon

After students watched the discussion-based concept cartoon animation, they entered the practice module and simulated how to carry out a discussion. Students inputted their login number to enter the lesson selection page and selected the lesson taught that day. After choosing the lesson, students entered the group selection page and chose their group, which led them to the group discussion page. Each group could discuss in the discussion area the mathematics concept that was taught. The concept cartoon and the discussion area were on the same page in the system, and students could look at the concept cartoon while discussing. The interface was shown in Figure 3 After completing the discussion, the leader of each group entered the answer in the answer area, and the answers of each group appeared in the dialogue box of the cartoon characters, which represented each group. The interfaces of discussion-based concept cartoon were shown in Figures 4 and 5.

Figure 3: The Concept Cartoon and the Discussion Area

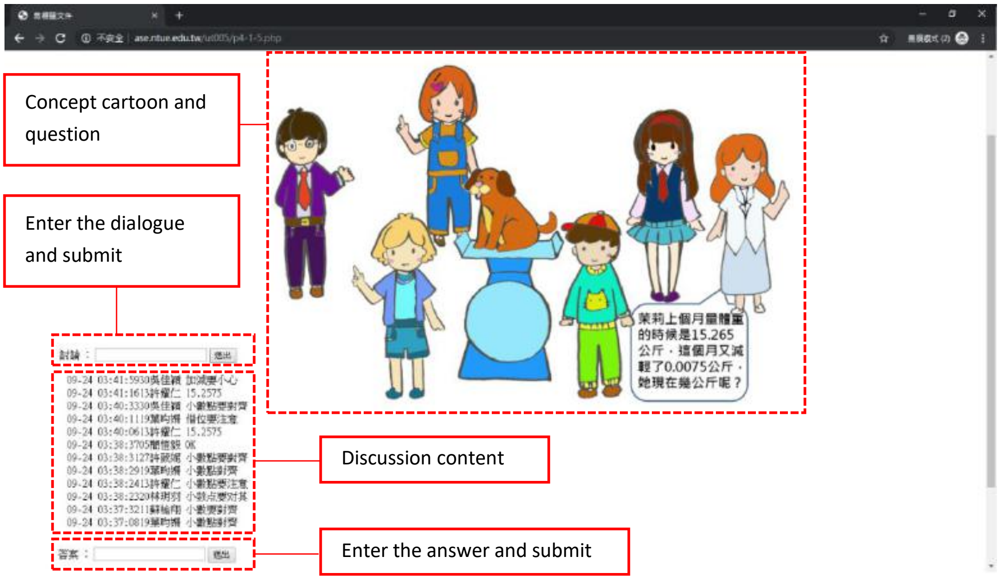


Figure 4: Interface of Discussion-based Concept Cartoons (Lesson: Addition and Subtraction of Decimals)

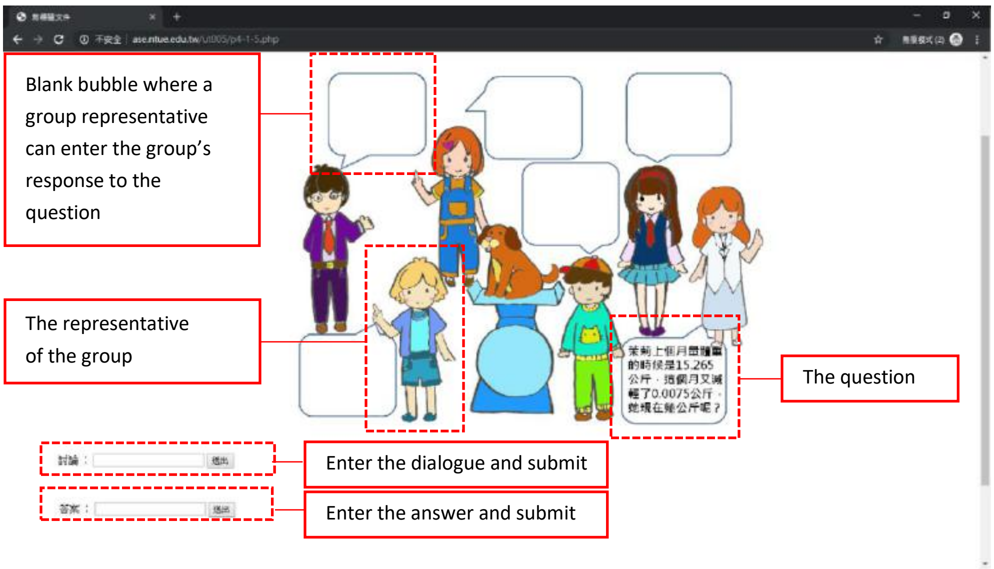
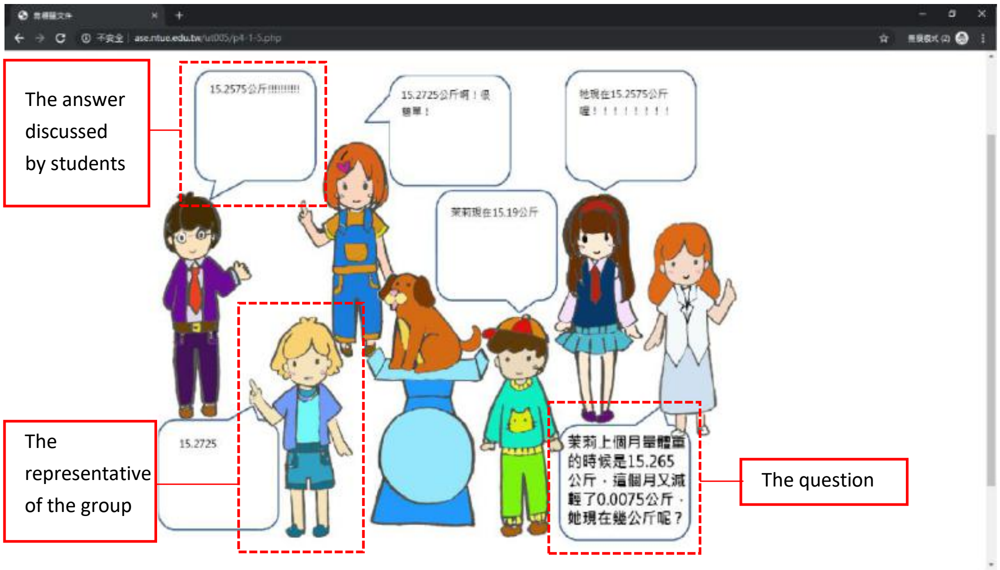


Figure 5 The Results of Discussion in Discussion-based Concept Cartoon



Teacher-oriented concept cartoon

After the teacher finished teaching using teacher-oriented concept cartoons, the teacher reviewed the mathematics concepts and provided the concepts for the concept cartoons. Then students directly selected the concept they believed to be correct without discussion. The interface of teacher-oriented concept cartoon was shown in Figure 6.

Figure 6 Interface of Teacher-oriented Concept Cartoons

Worksheet

After the teacher finished teaching, the teacher reviewed the mathematics concepts and gave students a worksheet with questions to practice the mathematics concepts. This teaching module did not use a computer.

Materials

The purpose of this study was to ascertain the effect of three different teaching modules on mathematics achievement. The research tools used include mathematics concept teaching materials, mathematics achievement tests, and computers.

Mathematics achievement test

The mathematics achievement test of this study contained items for the six concepts in the mathematics concept teaching materials used for the experiment. After the test was designed, it was evaluated by three experienced elementary school teachers to establish expert content validity. Before the formal test, a trial test was administered in another class not participating in the experiment to determine item difficulty and discrimination. The pretest and posttest were the same.

Data collection and analysis

This study used quantitative methods to analyze the effects of using different concept cartoon teaching modules and a worksheet teaching module on mathematics achievement. In addition, qualitative data was also included to show how students discussed in the class.

The quantitative data of this study were the results of the mathematics achievement test. The results were analyzed with the Chinese version of the statistical analysis software SPSS 20.0.

In the part of the study focusing on mathematics achievement, the test scores collected by the three groups (the discussion-based concept cartoon group, the teacher-oriented concept cartoon group, and the worksheet group) were separately tested in paired-sample *t*-tests to examine whether there was a significant difference between each group. Additionally, the pretest and posttest scores of the three groups were analyzed by ANCOVA to examine whether there were significant differences among the three groups of students.

Results and Discussion

Performance of the Three Groups of Students

The mean and standard deviation of students' scores in the pretest and posttest were shown in Table 2. The results showed that students who were taught with the concept cartoon system operated using a computer significantly improved (Table 2).

Table 2: Descriptive Statistics for the Pretest and Posttest Results on Mathematics Achievement for the Discussion-based Concept Cartoon Group, the Teacher-oriented Concept Cartoon Group, and the Worksheet Group

Test	Group	*n*	*M*	*SD*	*SE*
Pretest	Discussion-based concept cartoon group	29	77.10	17.00	3.16
	Teacher-oriented concept cartoon group	26	73.31	18.62	3.65
	Worksheet group	23	76.17	16.33	3.40
Posttest	Discussion-based concept cartoon group	29	92.83	10.97	2.04
	Teacher-oriented concept cartoon group	26	87.08	12.82	2.51
	Worksheet Group	23	82.61	15.94	3.32

The paired-sample *t*-test results showed a statistically significant difference for the case. As shown in Table 3, the results of the paired *t*-tests indicated a statistically significant difference in mathematics achievement for the discussion-based concept cartoon group and the teacher-oriented concept cartoon group ($p < .001$).

To understand the effects of different teaching modules on mathematics achievement, this study analyzed the effect size for the posttest of groups that reached the required level of significance (the discussion-based concept cartoon group and the teacher-oriented concept cartoon group). According to the effect size defined by Cohen (1988), a Cohen's *d* greater than 0.2 was a small effect size, one greater than 0.5 was a medium effect size, and one greater than 0.8 was a large effect size. The mathematics achievement effect sizes of discussion-based concept cartoons and teacher-oriented concept cartoons were both greater than 0.8, meaning that both were classified as having significant effects. This showed that concept cartoons had a significant effect. The paired-sample *t*-test results and effect sizes of the discussion-based concept cartoon group and the teacher-oriented concept cartoon group were shown in Table 3.

Table 3: Paired-sample *t*-test Results for Mathematics Achievement

Group	*M*	*SD*	*SEM*	95% confidence interval		*t*	*df*	Sig.	Cohen's *d*
				Lower limit	Upper limit				
Discussion-based concept cartoon group	15.72	16.00	2.97	9.64	21.81	5.29	28	.000***	1.02
Teacher-oriented concept cartoon group	13.77	15.41	3.02	7.54	19.99	4.56	25	.000***	0.93
Worksheet group	6.43	23.68	4.94	−3.80	16.67	1.30	22	.206	

***$p < .001$

Effect of Different Teaching Modules on Mathematics Achievement

Table 4 revealed that after removing the effect of covariate (pretest score) on the dependent variable (posttest score), independent variables (three different teaching modules) showed significant effects on the dependent variable ($F = 4.002$), indicating posttest scores would vary significantly with the experiment (independent variable) received by the subjects. Because the covariate analysis showed a significance level, and the effect size was 0.061, a post analysis was conducted.

Table 4: ANCOVA of the Pretest and Posttest Scores of the Three Groups

Source	*SS*	*df*	*MS*	*F*	Partial eta^2
Pretest	1160.045	1	1160.045	7.210*	.089
Group	1287.640	2	643.820	4.002*	.098

* $p < .05$

The Scheffe post-hoc results showed that comparing discussion-based concept cartoons and teacher-oriented concept cartoons did not reach the chosen level of significance. The worksheet group did reach the chosen level of significance. The worksheet group did not reach the chosen level of significance. For the discussion-based concept cartoon group and the worksheet group, $p = .01 < .05$; for the teacher-oriented concept cartoon group and the worksheet group, $p = .16 > .05$, indicating that discussion-based concept cartoons allowed students to achieve significantly more in mathematics compared with worksheets. Multiple post-hoc comparisons of the three groups were shown in Table 5.

Table 5: Multiple Post-hoc Comparisons of the Three Groups' Posttest Scores

(I) Group	(J) Group	*MD* (I − J)	*SE*	Sig.	95% confidence interval Lower limit	95% confidence interval Upper limit
Discussion-based concept cartoon group	Teacher-oriented concept cartoon group	4.89	3.44	.16	−1.96	11.75
	Worksheet Group	10.008*	3.54	.01	2.95	17.07
Teacher-oriented concept cartoon group	Discussion-based concept cartoon group	−4.89	3.44	.16	−11.75	1.96
	Worksheet Group	5.12	3.64	.16	−2.13	12.37
Worksheet Group	Discussion-based concept cartoon group	−10.008*	3.54	.01	−17.07	−2.95
	Teacher-oriented concept cartoon group	−5.12	3.64	.16	−12.37	2.13

* $p < .05$

The reason students in the discussion-based concept cartoon group performed better in the mathematics achievement test might be due to students not only understanding the mathematics problem through visualized concept cartoons, but also engaging in group discussions during which group members provided basic information to each other, and the exchange of ideas and opinions made concepts clearer. Hence, students in the discussion-based concept cartoon group performed significantly better than those in other groups on the mathematics achievement test. In addition, discussion-based concept cartoons allowed every student to speak. Students could express their opinions in the discussion area and could also provide answers without any restrictions. Hence, the discussion-based concept cartoon group performed significantly better on the mathematics achievement test than other groups. Constructivism focused on the development of cognition and the understanding of the depth of knowledge. It was believed that the development of cognition was not the result of individual growth or maturity, but the learner's initiative to reorganize and construct knowledge (Fosnot & Perry, 1996). In a constructivist classroom, the teacher was not the authority with one-way transfer of knowledge to students, but the organizer of knowledge, the coordinator and facilitator of student learning. The teacher organized the learning environment, put forward the problems to be solved, provided the necessary hardware and software for the students, carefully helped the students, encouraged the students' creativity, imagination and independence, and finally evaluated the results of students' cooperative activities (Alimisis, 2012).

Discussions in the discussion-based concept cartoon group showed that group members were able to provide basic information needed to solve problems, including finding the lowest common multiple and the common denominator before adding or subtracting fractions with different denominators. For example, student 28 in team 4 said, “First find the lowest common multiple for 5 and 4, which was 20”; student 29 said, “Change the fractions to the same denominator and then add them together”; student 10 said, “(Left) Needs to be changed to 8/20 and (Right) needs to be changed to 5/20, then add them together to get 13/20.” Furthermore, team members encouraged each other to express their opinions. For example, student 17 of team 4 said, “Why don’t you offer your opinion!” The results showed that using concept cartoons helped develop students’ critical thinking abilities, allowed students to reflect on their opinions or feelings, and created an active discussion environment in class for students to clarify mathematics concepts. This result was consistent with that of Bahrani and Soltani (2011), who indicated that concept cartoons enhanced discussion between students, as cartoons could create a light, playful mood, and all learners could respond instantly to cartoons according to their interpretation. Concept cartoons could be used as an alternative tool for developing critical cognitive development.

In the lesson on decimals, in addition to writing down the equation and directly giving the answer, students noticed the concepts of regrouping and aligning decimal points and place value during discussions. For example, student 7 in team 1 said, “There were four decimal places (0.0075),” and a student mistook 15.265 as 15.275 but found the mistake and corrected it after being reminded by a group member. For example, student 23 in team 1 said, “15.275 – 0.0075,” to which student 31 said, “Look again! It was 15.265 – 0.0075.” According to constructivism, students needed to use visualized learning tools in the knowledge construction process, which allowed them to construct meaningful learning in classes and discussions (Şengül, 2011).

A paired-sample *t*-test was used to analyze whether the pretest and posttest scores of the three groups were significantly different. The results showed that the pretest and posttest scores of the discussion-based concept cartoon group and the teacher-oriented concept cartoon group were significantly different, and the effect was significant; the pretest and posttest scores of the worksheet group did not reach the level of significance. The mathematics achievement of the teacher-oriented concept cartoon group and the worksheet group did not reach the chosen level of significance. Further analysis of the pretest and posttest performance of the two groups showed that the pretest and posttest performance of the teacher-oriented concept cartoon group reached the level of significance. In contrast, the worksheet group did not reach the chosen level of significance. This meant that the mathematics achievement of students using teacher-oriented concept cartoons improved more than students using worksheets. Even though the scores of the worksheet group improved, they did not reach the chosen level of significance, meaning that discussion-based concept cartoons were able to enhance students' mathematics achievement. This research result was consistent with the results of Şengül (2011) and Kaplan and Öztürk (2015), who argued that the application of concept cartoons in teaching mathematics could improve students' mathematics achievement.

Conclusions

To summarize the learning process of students in the discussion-based concept cartoon group, students correctly understood concepts through reflection, adjustment, and induction in the discussion process using concept cartoons. This study was the first of its kind and established a discussion-based concept cartoon system that differed from those of other studies, which used teacher-oriented concept cartoons. Unlike current references from around the world, this study also used discussion-based concept cartoons in the mathematics field rather than the science field for the first time in Asia. In addition, it was the students who proposed mathematics concepts in the discussion, rather than the teachers. The different teaching modules had significantly different influences on students' mathematics achievement. The concept cartoon system was operated using a desktop computer and a tablet computer, and the concepts of mathematics were chosen using a tablet computer. The desktop computer and tablet computer were not used during the teaching experiment with worksheet. The students who were taught with the discussion-based concept cartoons performed better. The use of discussion-based concept cartoons increased students' concentration. It allowed them to learn in an interactive learning environment, helping to clarify their misconceptions of mathematics concepts and benefiting their learning achievement. Debrenti (2015) mentioned that using discussion-based concept cartoons helped students understand and remember problems, which improved their mathematical reasoning. Currently, research on concept cartoons was still being conducted worldwide, and its practice was essential for the academic field.

Following the experiment, the researcher offered the following recommendations for teachers seeking to use mobile devices and discussion-based concept cartoons in teaching. Teachers should give students the opportunity to participate in learning activities and inspire them to develop and broaden their thinking process through peer interactions and opinion exchanges. Teachers need to pay attention to the discussions of groups to prevent the discussion area from becoming a chat room. Teachers can also use worksheets to let everyone write their opinions before engaging in discussion. When designing textbooks for mathematics concepts in the future, suitable mathematics concept cartoons could be used in electronic textbooks to aid the teaching and learning of mathematics concepts.

References

Alexander, R. J., & Wolfe, S. (2008). *Argumentation and dialogic teaching: Alternative pedagogies for a changing world*. London, England: Futurelab.

Alimisis, D. (2012). Robotics in education & education in robotics: Shifting focus from technology to pedagogy. In D. Obdrzálek (Ed.), *Proceedings of the 3rd International Conference on Robotics in Education* (pp. 7–14). Prague, Czech Republic: Faculty of Mathematics and Physics, Charles University.

Bahar, M., & Tongaç, E. (2009). The effect of teaching approaches on the pattern of pupils' cognitive structure: Some evidence from the field. *The Asia-Pacific Education Researcher, 18*(1), 21–45. doi: 10.3860/taper.v18i1.1034

Bahrani, T., & Soltani, R. (2011). The pedagogical values of cartoons. *Research on Humanities and Social Sciences*, *1*(4), 19–22.

Cankoy, O., & Tut, M. A. (2002, May). *Challenging and easy mathematical tasks for fourth graders in Turkish Republic of Northern Cyprus*. Paper presented at the first international educational conference, Famagusta, North Cyprus.

Chen, S. J., & Liu, S. T. (2002). 國小班級數學討論活動可行方案之探討 [The accessible teaching strategies of mathematics discussion in an elementary classroom]. *Chinese Journal of Science Education*, *10*(1), 87–107.

Choi, A., & Hand, B. (2020). Students' construct and critique of claims and evidence through online asynchronous discussion combined with in-class discussion. *International Journal of Science and Mathematics Education*, *18*(6), 1023–1040. doi:10.1007/s10763-019-10005-4

Cleaver, S. (2008). Comics and graphic novels. *Instructor*, *117*(6), 29–30, 34. Retrieved from ERIC database. (EJ792963)

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cooper, L. Z. (2005). Developmentally appropriate digital environments for young children. *Library Trends*, *54*(2), 286–302. doi: 10.1353/lib.2006.0014

Dabell, J. (2008). Using concept cartoons. *Mathematics Teaching Incorporating Micromath, 209*, 34–36.

Debrenti, E. (2015). Visual representations in mathematics teaching: An experiment with students. *Acta Didactica Napocensia*, *8*(1), 19–25. Retrieved from ERIC database. (EJ1064387)

Demirci, F., & Özyürek, C. (2017). The effects of using concept cartoons in astronomy subjects on critical thinking skills among seventh grade student. *International Electronic Journal of Elementary Education*, *10*(2), 243–254. doi: 10.26822/iejee.2017236119

Erickson, A., & Herbst, P. (2018). Will teachers create opportunities for discussion when teaching proof in a geometry classroom? *International Journal of Science and Mathematics Education*, *16*(1), 167–181. doi:10.1007/s10763-016-9764-4

Eryilmaz, A. (2002). Effects of conceptual assignments and conceptual change discussions on students' misconceptions and achievement regarding force and motion. *Journal of Research in Science Teaching*, *39*(10), 1001–1015. doi: 10.1002/tea.10054

Fosnot, C. T., & Perry, R. S. (1996). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (2nd ed., pp. 8–33). New York, NY: Teachers College Press.

Ge, X., & Land, S. M. (2003). Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions. *Educational Technology Research and Development*, *51*(1), 21–38. doi:10.1007/BF02504515

Gunbas, N. (2015). Students' mathematics word problem-solving achievement in a computer-based story. *Journal of Computer Assisted Learning*, *31*(1), 78–95. doi: 10.1111/jcal.12067

Guo, C. J. (1988). 從認知觀點探討自然科學的學習 [Explore the study of natural science from a cognitive perspective]. *Journal of National Taiwan College of Education*, *13*, 351–379.

Harskamp, E. G., & Suhre, C. J. M. (2006). Improving mathematical problem solving: A computerized approach. *Computers in Human Behavior*, *22*(5), 801–815. doi: 10.1016/j.chb.2004.03.023

Huang, C. S. J., Su, A. Y. S., Yang, S. J. H., & Liou, H. H. (2017). A collaborative digital pen learning approach to improving students' learning achievement and motivation in mathematics courses. *Computers and Education*, *107*, 31–44. doi: 10.1016/j.compedu.2016.12.014

Huang, K. H., & Ke, C. J. (2009). Integrating computer games with mathematics instruction in elementary school — An analysis of motivation, achievement, and pupil-teacher interactions. *International Journal of Educational and Pedagogical Sciences*, *3*(12), 2112–2114.

Jang, S. J. (1997). 討論教學的技巧與發現 [The skills and discovery of discussion teaching strategy]. *Science Education Monthly*, *12*, 2–8.

Kaplan, A., & Öztürk, M. (2015). The effect of concept cartoons to academic achievement in instruction on the topics of divisibility. *Mathematics Education*, *10*(2), 67–76. doi: 10.12973/mathedu.2015.105a

Kinchin, I. (2004). Investigating students' beliefs about their preferred role as learners. *Educational Research*, *46*(3), 301–312. doi: 10.1080/001318804200277359

Kusumaningrum, I. A., Ashadi, & Indriyanti, N. Y. (2018). Concept cartoons for diagnosing student's misconceptions in the topic of buffers. *Journal of Physics: Conference Series*, *1022*. doi:10.1088/1742-6596/1022/1/012036

Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, *22*(3), 215–243. doi: 10.1007/s10648-010-9125-8

Lipnevich, A., MacCann, C., Krumm, S., Burrus, J., & Roberts, R. D. (2011). Mathematics attitudes and mathematics outcomes of U.S. and Belarusian middle school students. *Journal of Educational Psychology*, *103*(1), 105–118. doi: 10.1037/a0021949

Liu, E. Z. F., Cheng, S. S., & Lin, C. H. (2013). The effects of using online Q&A discussion forums with different characteristics as a learning resource. *The Asia-Pacific Education Researcher*, *22*(4), 667–675. doi: 10.1007/s40299-013-0072-2

Lopez-Morteo, G., & López, G. (2007). Computer support for learning mathematics: A learning environment based on recreational learning objects. *Computers and Education*, *48*(4), 618–641. doi: 10.1016/j.compedu.2005.04.014

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. New York, NY: Routledge.

Mortimer, E. F. (1995). Conceptual change or conceptual profile change? *Science and Education*, *4*(3), 267–285. doi: 10.1007/BF00486624

Neumann, M. M., & Neumann, D. L. (2014). Touch screen tablets and emergent literacy. *Early Childhood Education Journal*, *42*(4), 231–239. doi: 10.1007/s10643-013-0608-3

O'Connor, M. C. (2001). "Can any fraction be turned into a decimal?" A case study of a mathematical group discussion. *Educational Studies in Mathematics*, *46*(1–3), Article 143. doi: 10.1023/A:1014041308444

Panaoura, A. (2012). Improving problem solving ability in mathematics by using a mathematical model: A computerized approach. *Computers in Human Behavior*, *28*(6), 2291–2297. doi: 10.1016/j.chb.2012.06.036

Pilli, O., & Aksu, M. (2013). The effects of computer-assisted instruction on the achievement, attitudes and retention of fourth grade mathematics students in North Cyprus. *Computers and Education*, *62*, 62–71. doi: 10.1016/j.compedu.2012.10.010

Samková, L. (2018). Concept cartoons as a representation of practice. In O. Buchbinder & S. Kuntze (Eds.), *Mathematics teachers engaging with representations of practice* (pp. 71–93). doi: 10.1007/978-3-319-70594-1_5

Schoppek, W., & Tulis, M. (2010). Enhancing arithmetic and word-problem solving skills efficiently by individualized computer-assisted practice. *The Journal of Educational Research*, *103*(4), 239–252. doi: 10.1080/00220670903382962

Şengül, S. (2011). Effects of concept cartoons on mathematics self-efficacy of 7th grade students. *Educational Sciences: Theory and Practice*, *11*(4), 2305–2313. Retrieved from ERIC database. (EJ962701)

Şengül, S., & Dereli, M. (2010). Does instruction of “integers” subject with cartoons effect students’ mathematics anxiety? *Procedia — Social and Behavioral Sciences*, *2*(2), 2176−2180. doi: 10.1016/j.sbspro.2010.03.302

Şengül, S., & Dereli, M. (2013). The effect of learning integers using cartoons on 7th grade students’ attitude to mathematics. *Educational Sciences: Theory and Practice*, *13*(4), 2526−2534. Retrieved from ERIC database. (EJ1027698)

Sexton, M., Gervasoni, A., & Brandenburg, R. (2009). Using a concept cartoon to gain insight into children’s calculation strategies. *Australian Primary Mathematics Classroom*, *14*(4), 24−28. Retrieved from ERIC database. (EJ885812)

Simon, S., Johnson, S., Cavell, S., & Parsons, T. (2012). Promoting argumentation in primary science contexts: An analysis of students’ interactions in formal and informal learning environments. *Journal of Computer Assisted Learning*, *28*(5), 440−453. doi: 10.1111/ j.1365-2729.2011. 00451.x

So, H. J., Tan, E., & Tay, J. (2012). Collaborative mobile learning in situ from knowledge building perspectives. *The-Asia Pacific Education Researcher*, *21*(1), 51−62.

So, W. M. W., & Ching, N. Y. F. (2011). Creating a collaborative science learning environment for science inquiry at the primary level. *The Asia-Pacific Education Researcher*, *20*(3), 559−569.

Walker, R. J., Spangler, B. R., Lloyd, E. P., Walker, B. L., Wessels, P. M., & Summerville, A. (2018). Comparing active learning techniques: The effect of clickers and discussion groups on student perceptions and performance. *Australasian Journal of Educational Technology*, *34*(3), 74−87. Retrieved from ERIC database. (EJ1185932)

Woolman, C. (2019). “Mindreading” from primary science: Using concept cartoons to develop theory of mind in 5−6-year-olds — A pilot study. *Education 3–13*, *47*(4), 395−409. doi:10.1080/03004279.2018.1489874

Yager, R. E. (1991). The constructivist learning module: Towards real reform in science education. *The Science Teacher*, *58*(6), 52−57.

Yang, Z. X. (1999). 討論教學法在班級教學上的應用 [Application of discussion-based teaching method in class]. *Class management*, *4*(3), 66−70.

資訊科技融入討論式概念卡通對國小五年級學生數學學習的影響

黃思華、李姿瑩

摘 要

本研究建置了一套討論式概念卡通的數學概念學習系統，探討三種不同教學模組，即討論式概念卡通教學（$n = 29$）、教師導向式概念卡通教學（$n = 26$）和學習單教學（$n = 23$），對台灣五年級學生數學學習成效的影響。兩組使用電腦操作概念卡通學習教學，另一組使用學習單教學。研究結果顯示，使用討論式概念卡通的組別，其數學學習成效顯著優於另外兩組；而且，使用電腦進行概念卡通教學的學生，其表現顯著優於傳統教學。

關鍵詞：概念卡通；討論式學習；數學成就；電腦輔助教學

HUANG, Tzu-Hua (黃思華) is Associate Professor in the Department of Education, University of Taipei, Taiwan.

LI, Tzu-Ying (李姿瑩) is a teacher in Ta-Pu Elementary School, San Xia District, New Taipei City, Taiwan.